Use of *Vitis vinifera* 'Autumn Royal' as a Potted Table Plant

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EXECUTIVE SUMMARY

Grapes are a very popular and versatile crop. With their origin near the Caspian and Black Sea, they do very well in warmer environments with generous amounts of sun. Grapes are mostly used for wine and table grape consumption. The most popular table grape variety is 'Autumn Royal.' When crafted into bonsai trees, the 'Autumn Royal' grape make a stunning beautiful and artistically cascading novelty tree.

I. INTRODUCTION

A. Study Species.

In this paper, *Vitis vinifera* L. will be reviewed with the intention of promoting a new idea for grape production. Overall, *V. vinifera* is one of the most popular grapes in the viticulture world today. From this species many wine and table grape cultivars have been developed. Although the table grape industry is smaller than the wine industry, it is still a major part of the fruit economy. The U.S. alone grew more than 7.1 million metric tons of table grapes in 2014 (Tordsen 2015). Being the fifth most popular fruit in the United States, grapes are wanted by consumers. There are many cultivars of *V. vinifera*; one of the most popular table grape cultivars is 'Autumn Royal' (Figure 1A). If *Vitis vinifera* 'Autumn Royal' could be developed into a stunted or bonsai form, consumers could grow the grapes right on their kitchen tables. Consumers could grow 'Autumn Royal' grapes in areas not suited for production, while also learning and exploring the beautiful Japanese art of bonsai. The following paper will describe the history of *V. vinifera*, production, and beneficial changes.

B. Taxonomic Classification and Geographic Distribution in the Wild.

The grapes genus, *Vitis*, is part of the family Vitaceae and its namesake. This family contains woody vines that have lobed leaves and tendrils, although some are shrubby trees (Creasy and Creasy 2009). Some other genera in this family are *Parthenocissus* (Virginia Creeper) and *Clematicissus*. In Latin the word "vitis" means vine and the word "vinifera" means winemaking. The meaning is fitting for this species because some cultivars are used for making wine, like the varietals Merlot and Chardonnay. Grape vines are considered lianas, meaning a climbing vine. They are woody vines that use tree trunks for support rather than developing their own

supportive trunk. In cultivation, a trellising system is used to support the growth of the vining trunk and branches. In botanical terms, the fruit is a true berry because the fruit is produced from the ovary of a single flower.

A grape plant is made up of two significant areas; the roots and the shoots (Figure 1B). The roots, which grow below ground, are one of the most important parts of the plant. They absorb nutrients and water, and anchor the plant to the soil. At the start of each growing season the roots form and expand within the soil (Weaver 1976). The finest and newest roots are called the feeder roots. These roots greatly increase the amount of absorption of nutrients and water (Weaver 1976). The Feeder roots can be seen in the bottom of the Figure 1B. As one travels upwards the trunk is above the roots. The trunk is primarily for supporting the shoots and branches. The trunk is above ground, along with the rest of the grape plant. In *V. vinifera* the trunk has bark that is stringy and sheds (Weaver 1976). From the trunk arise the main branches called the arms. The arms are the first and oldest branches. During pruning the majority of the arm is removed to encourage lateral shoot growth (Weaver 1976). The arms bear the canes and spurs that are kept at pruning for the next year's growth and crop (Weaver 1976). Canes are branches that are one or two years old. Out of the canes are the spurs. These are one-year-old branches that produce the fruit. It is important in pruning that the spurs are kept because grapes will only flower and fruit off of one-year-old growth (Weaver 1976). Off of the newest growth of the spurs develop tendrils, leaves, and buds. Tendrils are modified leaves that are used for anchoring the vine to tree trunks or rock walls in the wild, or a trellising system in cultivation. In most cultivars, the tendrils and leaves develop adjacent to each other on the branches. In other cultivars, the leaves and tendrils are opposite from one another. The leaves are the photosynthesizing powerhouse for the vine. Adjacent to leaves are the buds. Buds develop as compound buds. This means that there are actually three buds that grow very close together and look like one bud. The buds are named the primary bud, secondary bud, and tertiary bud. The primary bud usually develops into the shoot, but if it is somehow killed or damaged the secondary or tertiary bud will take its place

(Weaver 1976). The fruit is produced opposite of the leaves, similarly to tendrils. However, tendrils grow on the ends of the newest branches and fruit is produced closer to the main trunk of the plant. A cluster of flowers, or inflorescence, blooms about 6-10 weeks after the beginning of shoot growth (Weaver 1976). The fruit develops from one ovary. The berry is made up of the seed(s), pulp, and skin (Figure 2). Depending on the cultivar, the shape of the berry (Figure 3) and of the cluster (Figure 4) differs. In table grapes in the United States, little or no seeds are preferred with large amounts of pulp and thicker skin (Weaver 1976). The thickness of the skin helps protect the grape when traveling and distributing (Dami et al. 2005).

The genus *Vitis* contains two sub-genera, Euvitis and Muscadinia. The sub-genera differ in chromosome numbers, as well as phenotypes. For this reason, the two do not naturally cross, but with tissue culture techniques crosses have been made (Creasy and Creasy 2009). Grapes in the subgenus Euvitis have 38 chromosomes, whereas grapes in the Muscadinia subgenus have 40 chromosomes (Basiouny et al. 2001). Phenotypically, Muscadinia grapes have tight bark that does not shed. Its tendrils do not fork and when the berries mature the clusterlets easily detach from the vine. Euvitis grapes, on the other hand, have forked tendrils, bark that sheds, and berries that do not shatter when mature (Weaver 1976). Most of the species in the Euvitis subgenus originated in the Northern Hemisphere, whereas the Muscadinia subgenus originated in the Southern United States.

'Autumn Royal' is popular cultivar because of the fruit it produces and the relatively small amount of input needed in cultivating the vines. Its berries are large and have dark purple skin. The flesh on the inside is an attractive translucent yellow-green color (Wood 1997). They are one of the largest grapes currently on the market; the berries can weigh 8 grams or more (Dokoozlian, et al. 2000). They are oblong or slightly elliptical in shape and are generally seedless (Wood 1997). The bark is similar to typical *V. vinifera* cultivars. Its leaves are large and greatly lobed.

Figure 1A. *Vitis vinifera* 'Autumn Royal' berries

(http://forums.gardenweb.com/discussions/1487571/2012-seedless-grape-pictures)

Grapes are one of the most antiqued fruits and are steeped in history. Table and wine grapes are not native to the United States. Archeologists have agreed that the area between the Black and Caspian Seas and South of the Caucus Mountains is where the *V. vinifera* is native (Winkler et al. 1974). Figure 5 shows a map of the area with the orange filled area as the native range. Early human beings realized the potential and usefulness of the grape and took it with them on their trade routes spreading it all through out Asia and Europe (Creasy and Creasy 2009). It reached North America around the time of European settlement. *V. vinifera* was first introduced along the oceanic coasts of Southeastern and Southwestern United States (USDA). *Vitis vinifera* is considered a prohibited noxious weed in Ohio, unless it is cultivated for consecutive years (USDA 2012). Most species in the genus *Vitis* are hardy and can withstand temperatures down to -40°C. *V. vinifera* is more tender and can only withstand temperatures down to -15°C (Creasy and Creasy 2009). This limitation has decreased the introduced range of *V. vinifera* in the United States.

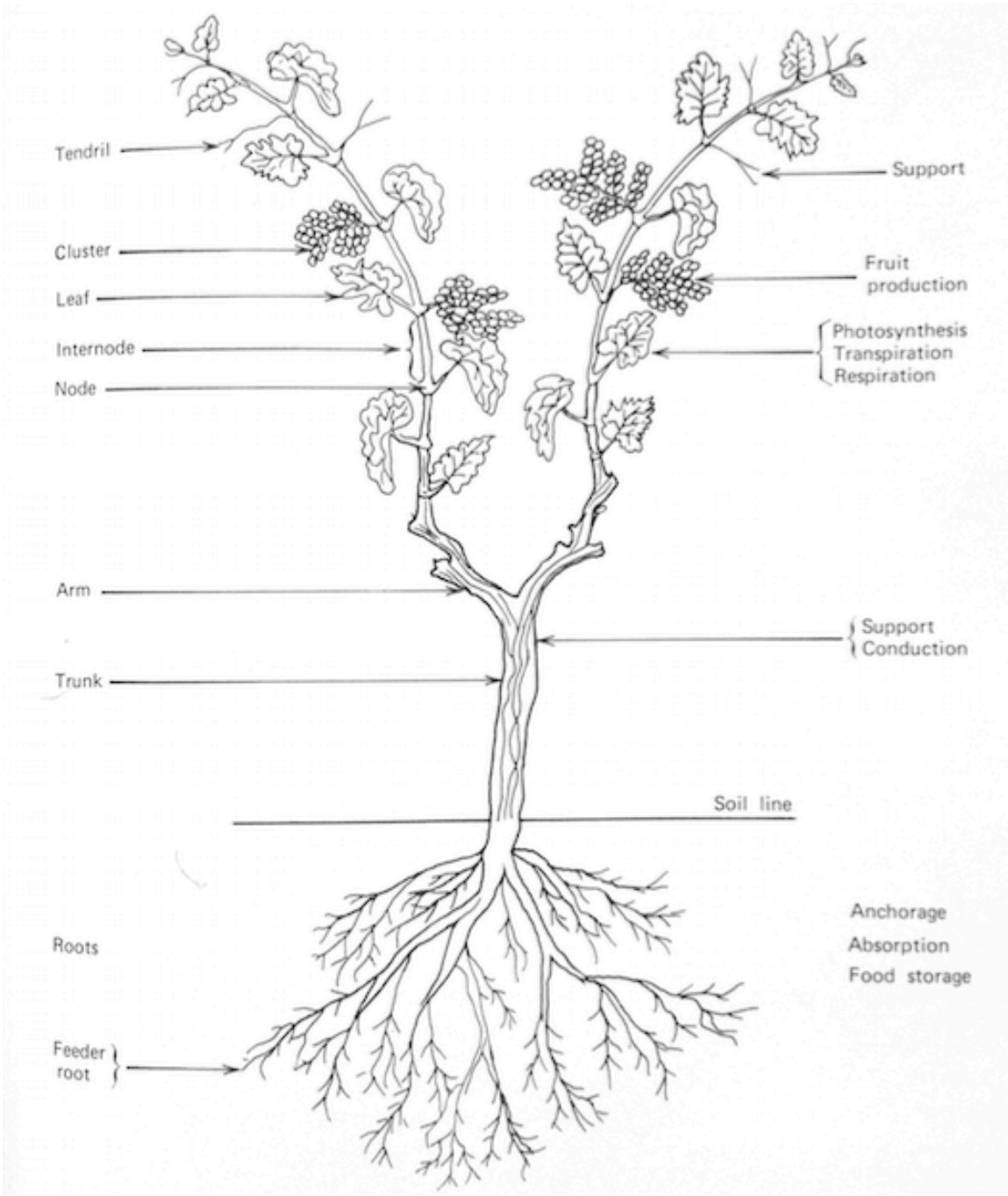

Figure 1B. Diagram of the physiology of grape vines

(Weaver 1976)

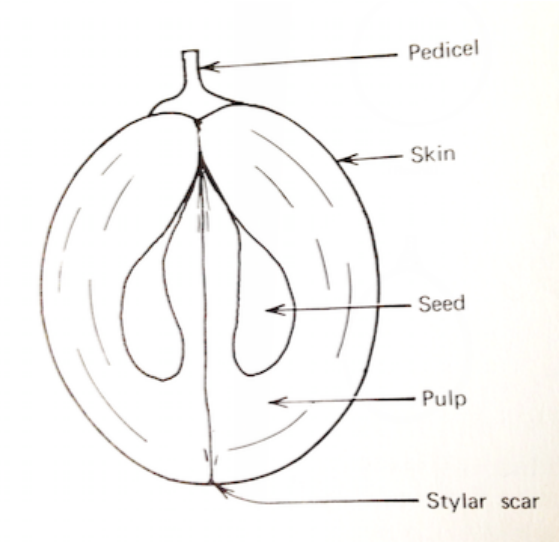

Figure 2. Diagram of grape fruit, a true berry

(Weaver 1976)

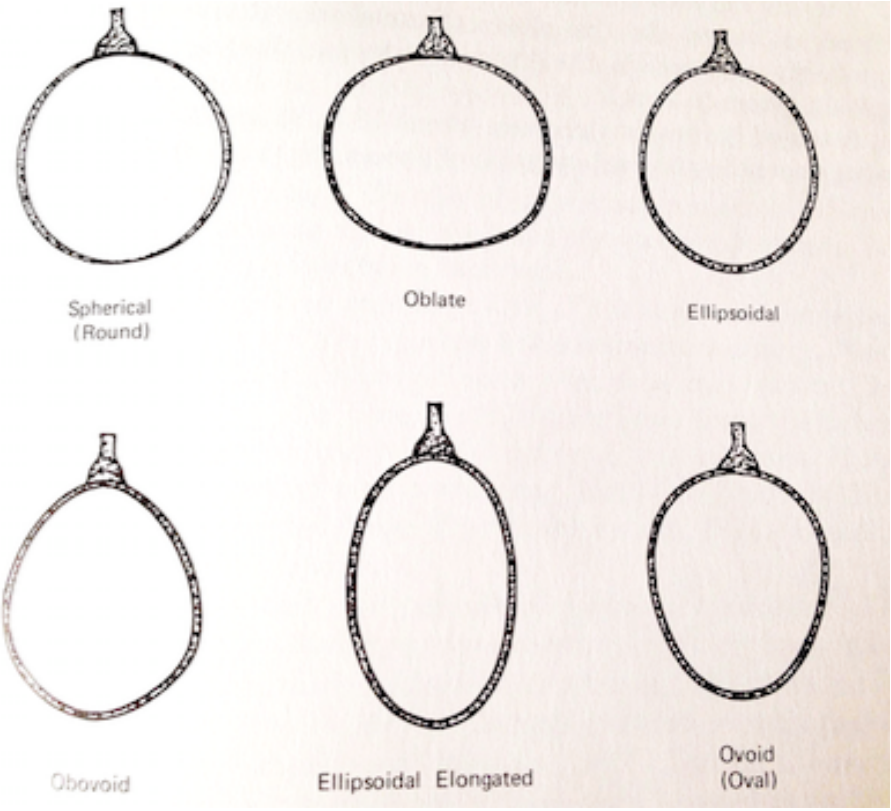

Figure 3. Diagram of the shapes of individual berries

(Weaver 1976)

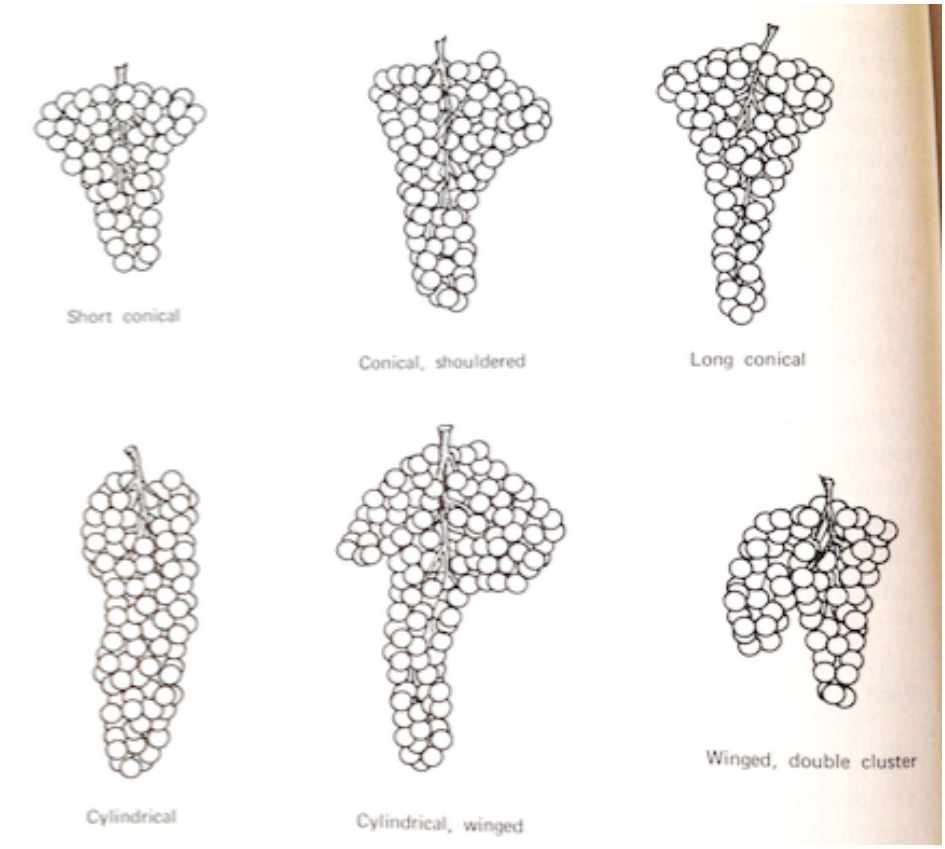

Figure 4. Diagram of the shapes of the berry bunches

(Weaver 1976)

Figure 5. The orange outlined area defines what archeologists believe to be the native range of *V. vinifera*, i.e. south of the Caucus Mountains and between the Black and Caspian Seas.

(https://shotberry.wordpress.com/page/4/)

II. CROP HISTORY

A. Breeding & Domestication.

Vitis sp. has been domesticated since the early humans roamed the earth. Seeds found in the refuse piles of early humans in South-Central Europe reveal that the grape was used back in the Bronze Age (Winkler et al. 1974). Residue on a potsherd from the time of the first permanent human establishment suggests that wine was being consumed and deliberately made and preserved (Berkowitz 1996). This finding was in a 7000-year-old Neolithic village in the mountains of Iran (Berkowitz 1996), the home of the wild grape. It is thought by historians and archeologists alike that grapes are one of the first plants to be domesticated by humans (Hyms 1965). Egyptian art depicts pictures of grapes in 1500BC (Creasy and Creasy 2009). In Photo 1 the process of picking and processing domesticated grapes for wine can be seen in the wall paintings of Nahkt. Nahkt was a scribe and serving priest for the Pharaoh. His tomb is dated back to 1550-1100BC by archeologists (Hirst 2010). When nomadic people realized the usefulness of the grape they took it on their trade routes and spread it to Palestine, Syria, Mesopotamia, and then to the Mediterranean (Creasy and Creasy 2009). Around this time the Greeks and the Romans introduced cultivating grapes to the people they conquered on their escapades. They started cultivating and spreading grapes on their journeys. They took it into Western Europe where it became really popular and the art of winemaking was increased. In 1616, Western Europeans brought grapes to North America or “The New World”. They also brought it to parts of South America on their exploratory campaigns. The Dutch introduced grapes to South Africa, where it had great amounts of success. Throughout the processes of introduction people used and developed different grape cultivars specifically for their region, and for different uses of the grape. *Vitis vinifera* was a very popular species and from it came the greatest number of cultivars. These cultivars include both table and wine grapes, the majority of them being wine grapes. In early times of domestication, grapes were usually grown on arbors. The arbors held

the vines high so that the grapes grew down and under the vine. This took a lot of space and was labor intensive. Now, grapes are commonly grown on hedge-like trellises instead of arbors. This is because there are larger amounts of grapes and vines being produced and grown in similar amounts of area. With trellising systems that are vertical and not horizontal, grapes can be trained to grow in smaller areas. This development helped commercialize grape production.

Photo 1. Wall painting from the tomb of Nahkt, a scribe and serving priest in ancient Egypt, shows workers harvesting (right) and then processing (left) grapes for wine. Circa 1550-1100 BC.

(http://www.osirisnet.net/tombes/nobles/nakht52/e_nakht_01.htm)

In the late 1800s the grapevine population was devastated by an infestation of the insect *Phylloxera sp.* This insect feeds on the roots and weakens the plant (Dami et al 2005). Figure 6 shows the insect and Figure 7 shows the galls formed on the leaves as a result of the insect. The yield, berry quality, and overall health of the vine decrease significantly until it dies (Dai et al. 2005). All species of European *V. vinifera* are susceptible to this insect. In 1869 Charles V. Riley and other scientist pinpointed the *Phylloxera* insect as the vector devastating grape production (Sorenson et al. 2005). He noticed that the species of *Phyxollera* in Europe and in America were identical and that it had originated in America (Sorenson et al. 2005). He proposed that the reason the European vines were so susceptible was because they had no resistance to the insect, which wasn't native to the area (Sorenson 2005). His summary of his findings helped convince French vintners to graft European scions onto American rootstocks that were resistant (Sorenson

et al. 2005). *Vitis riparia,* which is a river grape native to the United States, was used as the rootstock for grafting. Before this grafting rootstocks onto scions of a different variety did not happen very often. In France it was seen as affecting the overall quality of the grape product, be it wine or table grapes. After the infestation almost all of the grapevines are grafted onto *V. riparia* rootstocks (Pongrácz 1983). Now, it is common for specific wine and table grapes to be grafted onto a different rootstock for drought resistance or to increase overall vigor.

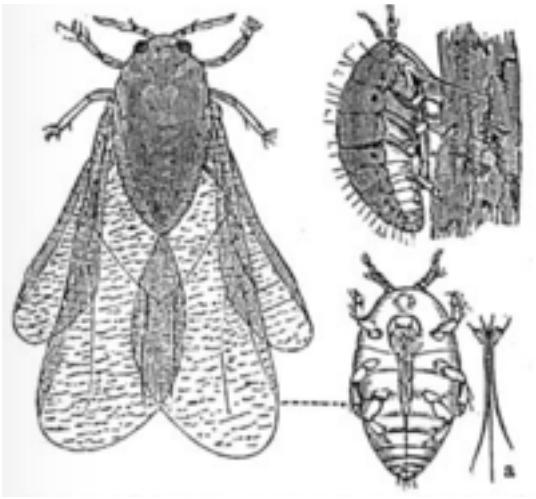

Figure 6. *Phylloxera* insect growth stages. Right is the juvenile pupae and on the left is the adult moth form.

(https://en.wikipedia.org/wiki/*Phylloxera*)

Figure 7. Galls on grape leaves because of a reaction to the *Phylloxera* insect

(http://entoweb.okstate.edu/ddd/insects/grapephylloxera.htm 1)

The distribution chain (Figure 8) for this crop starts at the breeding program. Since this crop is so old and very domesticated the chain starts at the breeder and not at finding the original specimen. When the breeder, public or private, has developed a variety that is tested and ready to be produced companies buy the grafts or seeds from the breeder so that they can produce the variety in bigger quantities. These companies then sell to vineyards or individuals so that they can plant it in vineyards. When the grapes are planted it takes about 5 years, depending on the variety, to produce high enough quality grapes to sell. The grapes are then sold to winemakers or distributors. Wine grapes are processed by winemakers to produce wine, table grapes are sent to

stores for consumers, and other grapes can be processed into juice, jams or jellies, and other foods.

The ‘Autumn Royal’ grape was bred for specific characteristics and introduced to the landscape as a crop. The popularity for table grapes encouraged the production of seedless grapes. David Ramming and Ron Tarailo of the United States Department of Agriculture-Agriculture Research Station (USDA-ARS) developed ‘Autumn Royal’ in Fresno, California and was introduced in 1996 (Dokoozlian, et al. 2000). This grape is a very popular seedless grape. Its distinctive characteristic of large fruit with a relatively small amount of inputs makes it popular among growers. ‘Autumn Royal’ is grown worldwide in temperate locations. In California ‘Autumn Royal’ is in the top ten most popular grapes (Wood et al. 2006). It is estimated that since its release in 1996, ‘Autumn Royal’ has been planted on more than 142 hectares (Dokoozlian, et al. 2000).

The distribution chain (Figure 8) for ‘Autumn Royal’ starts in Fresno, California at the USDA-ARS where the grape was produced. From here the vines are produced at wholesale nurseries, like Dave Wilson Nursery, who have the rights to produce the grape. Other smaller nurseries, like Bay Laurel Nursery, will buy bare root plants from the wholesale nurseries and sell them to growers. Growers, like Anthony Vineyards, will plant the bare root plants and grow the vines for many years. As it produces fruit the growers will sell the fruit to a distributor, like a Co-op. ‘Autumn Royal’ ripens around the beginning of October. It stores very well and can be from day of picking all the way to late December. The Co-op sells the fruit to grocery stores around the country. Consumers buy the delicious grape from the grocery store and bring it home for their families to enjoy.

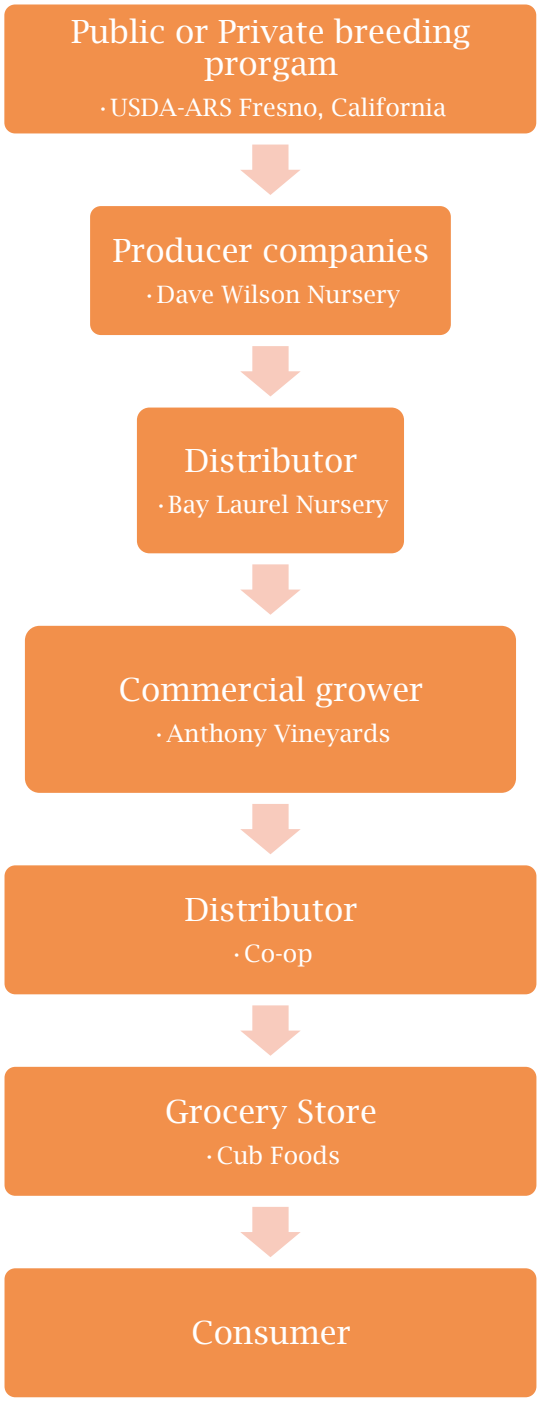

Figure 8. Horticultural distribution chain of the 'Autumn Royal' grape

III. PRODUCTION INFORMATION

A. Current Production Practices.

Grapes are a relatively versatile crop. They are perennial crops and grow in many areas of the world. The high number of cultivars makes the probability of finding a grape for a specific region quite high. The vegetative cycle of grapes can be seen in Figure 9. Even though grape vines can withstand a myriad of conditions, temperature has a major affect on fruit production (Law 2005). Grapes are propagated in many ways. The easiest way to propagate vines with the highest amount of success is by cuttings. Propagation can also be done by layering and grafting.

The main means of commercial reproduction for grapevines is hardwood cuttings or layer of canes (Dami et al. 2005). Almost all commercially grown grape cultivars are easily propagated by cuttings (Dami et al 2005). Cuttings ensure that the vines are true to the kind, instead of having genetic variability that can affect the overall product. Propagating by cuttings can be done in the field or in a greenhouse. When done in the field cutting are taken from the mother plant mid to late fall or early winter (Dami et al. 2005). They should include at least two nodes and three or four buds. The cuttings must be kept cool and moist until spring when they can be planted into the ground. When the soil is workable in the spring and all threat of frost has passed the cuttings can be placed in trenches. It is pertinent that the cuttings face the correct direction. The buds must be above the ground and the node below the ground (Dami et al. 2005). If placed upside down the cuttings will not root and instead will rot and die. Throughout the growing season the cuttings will develop shoots and roots. The management of disease and pests is very important during this stage because the lack of competition will increase vigor of the vines (Weaver 1976). The cuttings must be kept in the soil for at least one growing season. After a season of growth the cuttings can be dug up and placed into permanent rows

Cuttings can also be propagated in a greenhouse. This can be done to force growth in the spring and decrease the amount of time needed for establishment (Dami et al. 2005). The

technique is very similar as stated above. The cuttings are taken in late fall or early winter and must be kept cool and moist until early February. When removed from the cool moist environment cuttings can be placed in sand, perlite or vermiculite for rooting. Misting regularly is very beneficial (Dami et al. 2005). When some roots are developed and shoots are 5cm long the vines can be repotted into larger pots and moved to a conventional greenhouse (Weaver 1976). Vines are ready to be placed in the field when the shoots reach 30cm long (Dami et al. 2005).

Another process that can be used to propagate vines is layering. This is used when a vine needs to be replaced in an established vineyard. Vigorous one-year-old canes are used (Dami et al. 2005). The cane, which is still attached to the mother vine, is placed in a trench with terminal buds above the surface of the soil. The trench is filled with soil. The area under the soil must have at least one node. The node is where the roots will develop through the growing season, and shoots will develop from the buds. After one growing season the cane can be cut from the mother vine. The new plant can be transferred or kept in place. It is not suggested to move the vine after it is established (Dami at al. 2005).

Grafting propagated vines while also adding vigor to some cultivars. Since the epidemic of *Phylloxera*, grafting French and other European grapes onto American rootstock is necessary for resistance. Cultivars can also be grafted onto rootstocks for increased drought tolerance, disease and pest resistance, and increased nutrient uptake. The rootstock of the common Concord grape is the most resistant to *Phylloxera* (Dami et al. 2005). It also boasts a resistance to parasitic nematodes and other soil pathogens (Weaver 1976).

There are two main parts to a graft, the scion and the rootstock. The scion is a shoot taken from the desired vine, like ‘Autumn Royal.’ The scion and rootstock are often cut with notches that fit into each other for maximizing the amount contact between tissues (Weaver 1976). After being attached often propagators will put wax around the wound to protect the graft and to keep

moisture inside (Dami et al. 2005). The grafts are put in a moist chamber until callus forms. When the callus forms the grafts are then ready to be placed into the ground and rooted.

When laying out a vineyard it is important to take light, soils, and moisture into consideration. Grapes are lovers of full sunlight (Dami et al 2005). Placing vines is full sunlight is very important for the development of the fruit (Law 2005). Grape vines are very light feeders. If there is about 2% organic matter in the soil fertilizer applications are not necessary (Law 2005). Fertilizer is not pertinent but it does increase plant vigor. Moisture during bud break and flowering is important for the fall, but great amounts of moisture during fruit development is usually detrimental (Law 2005).

Trellising is very important to support the vines and increase fruit production. In general the more sunlight the leaves and fruit can be exposed to the greater the crop (Dami et al. 2005). The basic trellis is composed of two large posts at either end of a row with wires strung around the posts at the bottom, top, and middle. The wires help to contain the vines as they grow and to spread the shoots and leaves out to maximize sunlight.

Dormancy breaks in mid March and bleeding of excess moisture occurs. During this time the buds swell and burst in early April. Cytokinins are used to promote flower production right after bud break. If Gibberellins are used they promote tendril growth (Creasy and Creasy 2009). By Early June the vines are in full flower. Pollination occurs and the fruit begins to develop. The berries of vines less than five years old are not used in production because they are too bitter and small. The fruit set is very dependent on temperature. The slightest shift of temperature toward cold could abort the flowers or the fruit. It is said that good wines are made from grapes that are slightly stressed. This is true for both wine and for table grape production. When a grapevine is under small amounts of drought stress it causes the sugar in the berries to condense, making the berries sweeter. The ripeness of the berries can be determined by testing the acidity and sugar

content. Depending in the variety red grapes turn purple or red. Both red and white grapes become larger and softer as they mature (Law 2005).

When the berries are mature they are harvested. This is done by hand or mechanically. If harvesting is done by hand, workers go out into the vineyard, cut bunches of grapes, and place them into buckets. It is important that the grapes are handled carefully. If not, the grapes can crack or become soft. This is not beneficial for marketing because consumers prefer firm, intact grapes to eat. If berries are harvested mechanically a tractor with an attachment shakes the vines. This releases the grapes from the vines. The grapes are collected from the bottom of the attachment and placed in a large bucket for more processing and then distribution.

Grapes can be grown indoors in greenhouses. This is a fairly common practice. The production practice is very similar to that of outdoors. The grapevines are planted in the ground, sometimes inside the structure and other times outside of the structure and then pulled into the greenhouse. The grapes can be grown for decades like this, similar to outdoor production. When grown in greenhouses the fruit tends to be larger and better quality, especially for table grapes (Weaver 1976). This is because all of the climatic variables can be controlled for greatest amount of growth.

Usually this cultivar does not require Gibberellic acid or girdling for maximum fruit production. The best training suggested for ‘Autumn Royal’ is the Quadrilateral cordon training and spur pruning (Dokoozlian, et al. 2000). These practices produce most fruit and at the best quality. The roots of ‘Autumn Royal’ usually exhibit moderate or high vigor. The vigor of the plant can be increased when it is grafted onto rootstocks commonly used for table grapes (Dokoozlian, et al. 2000).

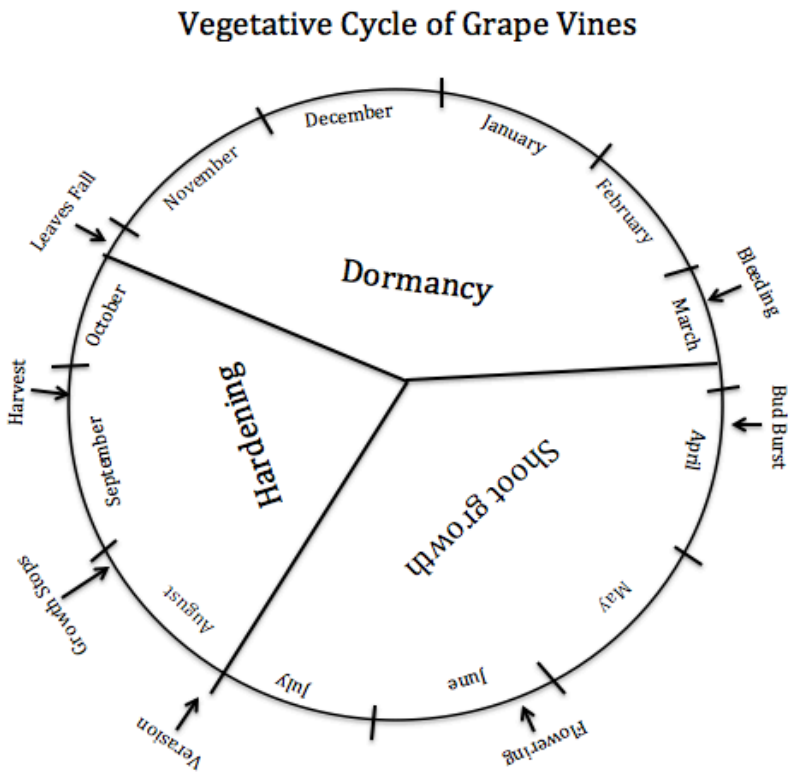

Figure 9. Grape vegetative cycle in one season of growth.

B. Current Production Statistics.

Vitis vinifera is the most produced grape in production with more than 90% of the world's grapes (Weaver 1976). Within the United States, California produces 85% of the domestic grapes, all of which are derived from pure *vinifera* cultivars (Weaver 1976). The area of total vines, all species, is about 7.9 million hectares across the world (Creasy and Creasy 2009). On top of the millions of hectares of grape producing land, the US still imports about 227,273 kilograms of table grapes from around the world (USDA 2012). The amount of land going into grape production has slowly increased through the years (Figure 4; OIV 2013). 'Autumn Royal' is in the top ten of California's most popular grapes. It's estimated that there is about 150 hectares of 'Autumn Royal' growing in California (USDA).

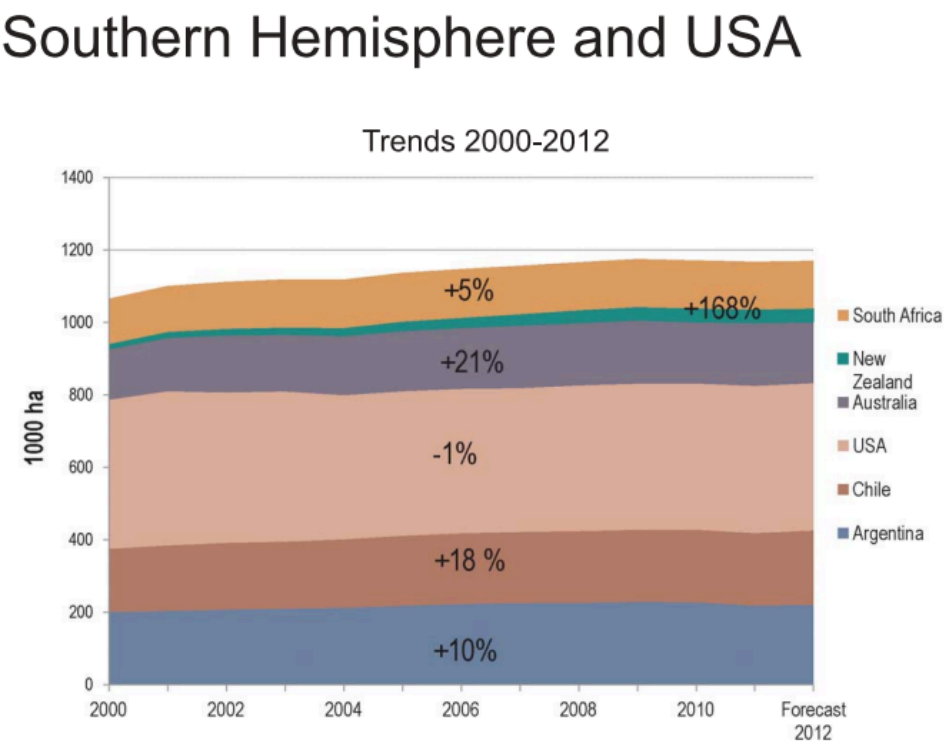

Figure 10. Graph showing the number of hectares of land in grape production in the Southern Hemisphere and the United States during 2000-2012 (OIV 2013)

IV. PROPOSED CROP TRANSFORMATION

A. Crop Production Change(s) for the Future.

The proposed change of this crop is to turn it into a potted household plant, specifically a bonsai. Bonsai plants are a beautiful way to bring the outdoors indoors while also practicing an ancient Japanese art form. Grapes are the canvas on which consumers can flex their artistic muscle. 'Autumn Royal' Grapes would be an ideal woody plant for bonsai because it is tolerant of certain stresses, moldable, and the large leaves provide a substantial amount of green color. As stated above 'Autumn Royal' does not need large amount of plant growth regulators for growth and fruiting. The grape bonsai would have greatest success when marketed as a novelty crop, such as miniature banana or orange trees. This marketing strategy would draw in consumers that are more interested in plants and have greater knowledge of taking care of specialty crops.

B. A New Production Schedule for Your Crop.

The production of a grape bonsai would change significantly from the usual commercial production. The crop would most likely have to be grown from seed. This could produce some problems because of the genetic variability and the difference it could make in the phenotype. The crop could be produced from a cutting but it would be more difficult and the final size of the tree would be relatively large for a bonsai. Once propagated the treatment to make it a bonsai would start immediately. When the seedling or cutting has a good root system established the grape bonsai can be placed in a small shallow pot. The soils should be about 40% sand with some organic matter (Kobayashi 1950). As the bonsai grows the roots need to be trimmed so that only growing areas of the roots are kept. This also contains the plant in the dwarfed form. The grape bonsai would need full sun and fertilization periodically throughout the growing season. Because of the small amount of soil and nutrients in a bonsai pot, the plant should be repotted every two or three years in the spring. Pruning should take place throughout the growing season. New buds and shoots can be trimmed to keep a upright or cascading shape. During the summer leaves will unfold and flowers will bloom, adding to the gracefulness of the plant. The ratio of the tree is very important. Grapes with their small flowers and large leaves add dimension while also providing a pleasing ratio of leaves and flowers to trunk. When the bonsai is three or four year old it can be marketed by novelty plant sellers such as the Gurney's Seed and Nursery Co.

Bonsai grapevine

(http://www.bonsaitreegardener.net/types/grapevine)

V. ACKNOWLEDGEMENTS

I would like to thank my host family in France for giving me a love of grapes and wine and for inspiring me to do research. I would also like to thank my mother for instilling in me a respect and appreciation for the natural world.

VI. LITERATURE CITED

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